Bio-Inspired Low-Temperature, Kinetically Controlled Nanofabrication of Semiconductor and Ferroelectric Thin Films and Nanoparticles for Energy Applications

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We have developed a generic new biologically inspired low-temperature route for the kinetically controlled catalytic synthesis of a wide range of nanostructured metal oxide, -hydroxide, -phosphate and bimetallic perovskite semiconductor thin films and nanoparticles without the use of organic templates. Post-synthesis conversion to the nitrides and sulfides has been demonstrated. Because synthesis occurs at low temperature, this new biologically inspired synthesis method yields materials with novel structures and properties that in some cases cannot be attained by conventional high-temperature methods. Because no organics are used, the method yields high purity inorganic semiconductors, and thus is potentially integrable with MOCVD, CMOS and other conventional manufacturing methods.

Employing gentle catalysis at low temperature, this method can preserve the intermetallic organization of bimetallic precursors that are thus incorporated into crystalline solids as bimetallic molecular units without phase segregation. This has led to the first low-temperature synthesis of 6 nm barium titanate nanoparticles with low polydispersity, good electronic properties and no organic contaminants. Use of these nanoparticles for improved safety of lithium-ion batteries will be discussed. We also have used this process for the low-temperature synthesis of a wide range of supported (substrate-grown) and unsupported (free-standing) nanostructured thin films. Several of these materials exhibit high surface area of single-crystal domains, strong absorption in the visible and high dopant density, making them potentially attractive for photovoltaic applications. Work at the Molecular Foundry developing proof-of-principle solar cells will be described. Related materials made by this method offer advantages for high power-density 3-dimensional batteries. A wide range of other materials made by this low-temperature process offer unique combinations of structures and properties not readily attainable by conventional high-temperature processes; these exhibit potential advantages now under investigation for improved energy conversion and storage, ferroelectric random access memory (FeRAM), infrared and piezoelectric detectors, optoelectronics and flexible displays.